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XXI.—*On the* Cidaridæ *of the Oolites, with a description of some new species of that family.* By Thomas Wright, M.D. &c.*

[With three Plates.]

The Echinoderms form the highest class of the radiated animals; it includes organisms which are either fixed or free, composed of a regular but very complicated skeleton, secreted by and inclosed within organized membranes, and often preserved in admirable perfection in the fossiliferous strata of all periods of the earth's history. The study of this class, although hitherto much neglected by geologists, presents many points of importance to the progress of their science, for the test of Echinoderms exhibits characters of more import and significance than those afforded by the shells of Mollusca. Unlike the testaceous covering of that class, the test of Echinoderms constitutes an internal and integral part of the animal, participating in its life, intimately connected with the organs of digestion, respiration and generation, as well as with those of locomotion and vision, and having in consequence many of the distinctive characters of the organism impressed upon it.

In all Echinoderms, the external parts of the body, with the organs of locomotion, are disposed around a common centre; in the spherical forms they are arranged in rows like the lines of longitude on a terrestrial globe, and the mouth and the anus are situated at the opposite poles: the elements of the body are repeated several times in the composition of the skeleton.

It has been shown by M. Agassiz† that the radiated type of

* Read at Cheltenham at the Meeting of the Cotteswold Naturalists' Club, June 24, 1851.

† Prodrome d'une Monogr. des Echin., Mém. Soc. de Neuchâtel, tom. i. p. 168.

structure observable in this class can be resolved into a modification of the bilateral symmetry seen in the higher groups of the animal kingdom. The elements of the skeleton are arranged on two sides of a median line. If we take for example the *Spatangus purpureus,* we observe that the test is elongated in the direction of the line which connects the mouth with the anus; the mouth being situated at the base and nearer the anterior border of the test, whilst the anus occupies an elevated position on the posterior border. Were we to make a transverse section of the Spatangus, we should have an oral or anterior half, and an anal or posterior half; whilst, on the contrary, were we to split the test asunder in the line of its long diameter, we should have the right half and the left half of the body. The five ambulacral areæ are unequal. The anterior area is not identical with either of the others; the first pair are symmetrical, but differ from the second pair, which are likewise symmetrical; the bilateral symmetry of these oblong Spatangoidæ is therefore very evident. In the globular forms of Cidaridæ, however, a more careful study is requisite to make the demonstration complete. In them the test is formed of polygonal plates united together by sutures and divided into ten segments, of which five are named ambulacral areæ, and five interambulacral areæ, each area being formed of two columns of plates; the ambulacral and interambulacral areæ alternate with each other, and are separated by ten zones of small plates perforated for the passage of tubular retractile organs connected with locomotion and respiration, and forming the poriferous avenues.

The test of *Echinus sphæra* is composed of twenty distinct zones of elementary parts, which are narrow at the summit, from whence they divide in rays, and gradually increase in width towards the circumference or equator, where they are widest; they again contract as they approach the mouth, which occupies the base. The symmetrical disposition of these elementary zones occasions the radiated form which characterizes the Cidaridæ. Besides the plates of the ambulacra, interambulacra, and poriferous avenues, the summit of the test is furnished with a circle of plates surrounding the anus, composed of five larger plates in relation with the generative organs, and called ovarial, and five smaller plates disposed between them, in which are lodged the organs of vision, and called ocular; each of the ten plates is perforated with a small hole for giving passage to the genital ducts and for lodging the eyes. This anal circle of plates is called the apical rosette or disc.

The ovarial plates occupy the summit of the interambulacral areæ, and the ocular plates the summit of the ambulacral areæ; the ovarial plates are not all of equal size or of the same structure;

one is larger and more prominent than the others, presenting a spongy porous surface, and called the madreporiform plate; it is placed opposite the ambulacra, which is the analogue of the anterior area in the *Spatangus*, and occupies therefore the posterior border of the apical disc, affording thereby a key for ascertaining the antero-posterior diameter of the body; the other four ovarial plates are disposed in pairs before the single madreporiform plate. The polygonal plates of both areæ are arranged in double vertical rows, two columns of ambulacral plates alternating with two columns of interambulacral plates; the plates of each pair are united by a zigzag suture formed by the re-entrant angles of the plates; the plates of the ambulacra are united to those of the interambulacra by minutely serrated edges. The poriferous zones have small plates, the sutures of which cut through the centre of the holes, by which arrangement the enlargement of the foramina with the growth of the test is provided for.

The surface of the test is covered with tubercles for supporting spines; these are of two kinds, the principal and the miliary tubercles. The principal tubercles are in general raised on mammillated eminences with or without crenulations at their summit, and arranged in vertical rows on the sides of the areæ between the mouth and the anus. The miliary tubercles are much smaller and more numerous; they are not disposed with the same regularity, but are frequently scattered on the surface of the plates, or disposed in circles around the bases of the principal tubercles.

Each tubercle supports a spine, the size of which corresponds with that of its tubercle; the spines are composed of three distinct parts, the stem, the neck, and the articular head. The stem is more or less elongated and of various forms; the head is surrounded by a raised ridge, and has a concave excavation for its articulation with the tubercle; the head is separated from the stem by a smooth neck, the extent of which varies in the different species. The spines present very numerous modifications of size, form and sculpture, which are closely connected with specific distinctions; some are elongated, cylindrical, fusiform, or subulate; others are compressed, spatuliform, or triangular; whilst others, on the contrary, are expanded, pyriform or claviform.

The surface of the spines is smooth, striated, or furnished with granules, prickles, or other asperities disposed in regular order or scattered at hazard over the stem. The same individual has its test occupied with different kinds of spines; hence the great importance of obtaining these appendages in connection with the test.

We have made the following estimate of the number of separate pieces which enter into the composition of the test of *Echinus sphæra*:—

Interambulacral areæ	32 plates in each column	32×2×5=	320 plates.
Ambulacral areæ	80 do. do.	80×2×5=	800 do.
Poriferous avenues	160 do. do.	160×2×5=	1600 do.
Apical disc	10 plates		10 do.
Each interambulacral plate supports 10 tubercles		320×10=	3200 tubercles.
Each tubercle supports a moveable spine			3200 spines.
Each ambulacral plate supports 2 tubercles ...		800× 2	1600 tubercles.
Each tubercle supports a moveable spine			1600 spines.
There are 70 rows of holes in each avenue, and in each row these six holes are disposed in pairs obliquely		70×6×10=	4200 foramina.

The mouth in the Cidaridæ is situated at the centre of the basal surface, and provided with five jaws, each armed with a long tooth; the jaws are united by ligaments and moved by numerous muscles belonging to the voluntary class.

According to Prof. Brunner, the analysis of the test of *Echinus lividus* gave the following result as its chemical composition:—

Carbonate of lime	96·27
Sulphate of lime	1·53
Carbonate of magnesia . . .	0·93
	98·73

The fracture of the test and the spines presents a peculiar crystalline surface altogether unlike that of the external skeleton of other Invertebrata, depending probably on the manner the salts of lime and magnesia are deposited in the cells of the animal basement membrane. The external and internal surfaces of the test are covered by organized membranes, which extend through the sutures and invest the spines and pedicellariæ, and are the producers and the sheath of the test and its appendages.

The mode by which the spheroidal test of an Urchin maintains its original form, whilst it increases in all directions, is easily understood after what we have stated relative to its composition. The viscera of the animal are inclosed in this fragile and inflexible globular crust, which is never shed like the external skeleton of the Crustacea, but grows by a process which has some analogy with the expansion of the skull in the vertebrate classes. By the division and subdivision of the hollow globe into a number of elements inclosed between two layers of membrane, additions are made to the periphery of the plates, whereby they are enlarged and increase in thickness in proportion to the requirements of the animal, so that the form of the test is maintained and its expansion provided for at the same time: the difference between the test of a young and an old Urchin chiefly consists in the number and size of the plates entering into the composition of the same. The new plates are developed around the oral and anal poles, but chiefly near the latter region, where

we may observe in young Urchins small plates loosely connected together and supporting incomplete spines.

The numerous genera of the family Cidaridæ are distributed by M. Agassiz into four groups :—

1. The Cidaridæ are characterized by their thick test, narrow ambulacra, and large principal tubercles in the interambulacral areæ.

2. The Salenians are characterized by the development of their apical disc, and the presence of an additional central or suranal plate in the same.

3. The Echinidæ have a thin test, and numerous small principal tubercles in the ambulacral and interambulacral areæ.

4. The Echinometrans have an elongated oblong form in a direction oblique to the antero-posterior diameter of the test.

Family Cidaridæ*.

Form circular. Mouth central, situated at the inferior pole, closed by a buccal membrane which is either naked or covered with granules. Anus opposite the mouth, opening in a ring composed of ten plates, five of which appertain to the genital, and five to the visual organs. The antero-posterior diameter is indicated by the median madreporiform body which becomes united to the single ovarial plate. The plates of the test support tubercles disposed in regular order for carrying moveable spines of various forms, some of which are proportionably large. The organs of mastication consist of five jaws, each armed with a long tooth. This framework is articulated to the test by several arched processes called auricles.

Genus Cidaris, Lamk.

Form circular, test thick, flattened at both poles. Ambulacral areæ narrow, about one-fourth the diameter of the interambulacral areæ, and covered with small close-set granules. Pores disposed in simple pairs. The principal tubercles in the interambulacral columns are perforated, and carry large heavy spines which are smooth or furrowed, spiny or granular. The ovarial plates are large, pentagonal and equal ; the ocular plates are small and triangular, and wedged between the ovarial. The mouth is circular and without indentations ; the buccal membrane is covered with imbricated scales upon which the ambulacral pores extend. Jaws powerful, composed of five pyramids, the branches of

* The group of Cidaridæ includes six genera : *Cidaris*, Lam., *Goniocidaris*, Desor, *Hemicidaris*, Agass., *Acrocidaris*, Agass., *Acropeltis*, Agass., *Palæocidaris*, Agass.

which are not united at their summits. Teeth channelled, not carinated on their internal surface. This genus admits of a natural division into two types; in the one the tubercles are smooth, in the other they are crenulated at their base.

The first type.—*Tubercles with the base not crenulated. Are found in our present seas, and fossil in the carboniferous, triasic, cretaceous, and tertiary rocks. They are not found in the Oolitic strata, to which group the present paper is restricted.*

The second type.—*Tubercles with the base crenulated. Comprehends oolitic and triasic forms.*

The circular mouth without indentations serves to distinguish the genus *Cidaris* from the genus *Hemicidaris*. The form of the ambulacral areæ, the number and arrangement of the granules on the same, the size of the tubercles, and the number of their crenulations afford good specific characters. The ovarial and ocular plates are seldom preserved. The lantern and teeth ought to be carefully studied, as they are sometimes found detached; the spines likewise yield good specific characters, but they are seldom preserved along with the test.

Cidaris Fowleri, Wright, n. sp. Pl. XI. fig. 5 *a, b, c.*

Test spheroidal, depressed at both poles; ambulacral areæ flat, narrow and undulated, furnished with two rows of small, regular marginal granules and two rows of central blunt irregular microscopic granules; poriferous avenues wide; pores oblong and distant; interambulacral areæ furnished with two rows of from 8–10 principal tubercles; intertubercular spaces wide and covered with small granulations; spines large, with irregular forward-directed prickles.

Height 1 inch $\frac{1}{10}$th, transverse diameter 1 inch and $\frac{8}{10}$ths. Specimens from the upper stages of the Oolites measure in height 1 inch and $\frac{8}{10}$ths, transverse diameter 2 inches and $\frac{8}{10}$ths.

Description.—This beautiful Urchin has been catalogued as *C. coronata*, but it presents characters very distinct from that form; a fact which has been ascertained by comparing *C. Fowleri* with the typical specimens of *C. coronata* in the British Museum: the latter species has hitherto been found only in France, Germany, and Switzerland, and figured in the works of Goldfuss, Agassiz, and Cotteau. In the Swiss Jura *C. coronata* characterizes the terrain à chailles, a local formation, the greatest similarity to which exists palæontologically with the lower calcareous grit of Yorkshire; in l'Albe Wurtembergeoise it appertains to the Coralline Oolite.

The ambulacral areæ of *C. Fowleri* are slightly serpentine and

ribbon-shaped, and nearly of a uniform breadth throughout. The poriferous avenues are broad; the pores are oblong and set in pairs in a single file at short distances apart. The areæ are flat, slightly raised, and have four rows of granules; the external rows consist of larger granules, which range regularly on the margins of the areæ; the internal rows consist of small, flat, almost microscopic granules; there are fifteen pairs of holes opposite each of the large tubercular plates.

The interambulacral areæ are formed of broad plates; the zigzag median sutural line is very clearly defined; each column contains from eight to ten primary tubercles, so that the test of this Urchin supports from 80 to 100 large spines. Each plate is occupied with a smooth areola slightly furrowed at its circumference and raised into a boss towards the centre. The summit of the boss is sculptured with fifteen deep crenulations; from the boss arises a short cylindrical stem terminated by a small hemispherical deeply perforated spinigerous tubercle, the diameter of which exceeds a little that of its stem; the margin of each areola is bounded by a circle of fifteen prominent granules, some of which from the equator to the anal pole are raised upon broader bases. There is a granular circle around each areola, but from the equator to the buccal pole one row of granules is common to two areolæ. The interareolar spaces are covered with small close-set granules of two different sizes. The mouth is large, and is half the diameter of the test at the equator. In the specimen before me the five strong pyramids of the lantern are armed with conical triangular teeth *in situ*. The anal disc was broken in all the specimens hitherto found.

The spines are never seen attached to the test, but in the same bed and lying near some of these Urchins, long cylindrical slightly flattened spines have been found about $1\frac{1}{2}$ inch in length and from 2 to 3 lines in diameter, with a crenulated base, short neck, and having the surface of the flattened stem covered with short sharp prickles, the points of which are directed forwards; these spines most probably belonged to *C. Fowleri*, as it is the only Urchin found in the same bed whose test could support such large spines (fig. 5 *c*).

Affinities and differences.—*Cidaris Fowleri* resembles *C. Blumenbachii* in the general form and structure of the test, but it differs from that well-known species in the flatness of the ambulacral areæ, in the greater breadth of the poriferous avenues, and in having a greater number of plates in the interambulacral columns; the granulated space between the principal tubercles is wider, and the granular wreath encircling the areolæ is likewise composed of smaller granules. It differs from *C. Parandieri*, Ag., in having a greater number of tubercular plates in the

interambulacral areæ. It resembles *C. maxima*, Goldf., in the general outline of the test, the width of the granular spaces between the tubercles, and in the spines supposed to belong to *C. Fowleri* being armed with short forward-directed prickly processes like those of *C. maxima*. It differs from *C. propinqua* in having a greater number of plates in the interambulacral areæ.

Locality and stratigraphical range.—*Cidaris Fowleri* was obtained from the ferruginous beds of the Pea-grit at Crickley Hill. I have dedicated this beautiful species to my friend Charles Fowler, Esq., who obtained two fine specimens from this locality, and to whose generosity I am indebted for the one which has served for my description and enriches my cabinet.

Cidaris Blumenbachii, Munster.

Syn. *Cidarites Blumenbachii*, Munst.; Goldfuss, Petref. Germaniæ, t. 39. p. 117.
Cidaris Blumenbachii, Agassiz, Echin. Foss. 2nd part, t. 21. p. 61; Park. Org. Rem. vol. iii. t. 4. fig. 15.
Cidaris florigemma, Phillips, Geol. of York. t. 3. fig. 12.
Cidarites Blumenbachii, Munst.; Cotteau, Etudes Echin. Foss. t. 10. p. 108.

Test circular, inflated at the sides and depressed at the poles; ambulacral areæ narrow, elevated, undulated, and furnished with four rows of granules; interambulacral areæ with two rows of from six to seven tubercles; areolæ approximated, elliptical and excavated, and surrounded by a circle of small tubercles; spines large, thick, subcylindrical, and ornamented with longitudinal rows of granules; neck short and smooth.

Height 1 inch and $\frac{4}{10}$ths, transverse diameter 2 inches; spines 1 inch and $\frac{8}{10}$ths in length, and $\frac{4}{10}$ths of an inch in diameter.

Description.—This typical species was very abundant in the seas which deposited the Coralline Oolites of Europe. It has a globular form considerably depressed at the poles; the ambulacral areæ are narrow, nearly of a uniform breadth throughout; they are much undulated and furnished with four rows of granules; the external rows are larger, more regular and prominent, and more developed towards the base than the internal rows. The poriferous avenues follow the undulations of the areæ; they are narrow, and lie in a groove formed by the prominent granules of the ambulacral and the external marginal granules of the interambulacral areæ. The interambulacral areæ are five times as wide as the ambulacral, and are occupied with two rows of large prominent tubercles from six to seven in each row, which are supported on large mammillary eminences gradually rising from smooth elliptical areolæ. The mammæ at their summits

are sculptured with from 18–20 crenulations, and the areolæ are separated from each other by a circle of granules made more prominent, inasmuch as they are raised on oval elevations of the test. The principal tubercles are small and closely set together at the base, but at the equator, and always at the upper part of the test, they become largely developed; the narrow central space between the ranges of the large tubercles is occupied with an abundant granulation, the granules of which are smaller, however, than those encircling the areolæ.

The mouth is armed with powerful jaws and teeth, which are not, however, preserved in the specimens before me; the apical disc is unknown.

The spines attain a great size; they have an elongated thick subcylindrical form which suddenly expands above the neck, and then gradually tapers towards the apex; their surface is covered with small granulations, very uniform in size and disposed in longitudinal rows; the tubercles of the adjoining rows alternate, and each series is connected by a filament which passes from one tubercle to another; at the summit of the spine the granules become elongated, and expand to form a radiated star-like disc; the neck of the spine is short and smooth, the articulating head is small, and the rim of the acetabulum is encircled with crenulations.

Affinities and differences.—*C. Blumenbachii* is distinguished from *C. Fowleri* in the extreme narrowness of the ambulacral areæ, the size and prominence of the granules which cover the same, and in the closer approximation of the pairs of pores in the avenues. The interambulacral areæ are wider, whilst the central granular space between the tubercles is narrower; there are fewer ranges of tubercles in the areæ, and the areolæ are encircled by much larger granules; but it is in the structure of the spines that the greatest difference is observed: instead of the well-known regular form of the tubercles so constant in the spines of *C. Blumenbachii*, the spines of *C. Fowleri* are compressed and covered with irregular rows of prickles.

Locality and stratigraphical range.—This Urchin is very characteristic of the Coralline Oolites of Wilts, Oxfordshire, and Yorkshire; we have never seen it either in the Inferior or the Great Oolite; our specimens are from the Coral Rag of Wiltshire; it occurs in France in the corallian stages of Châtel-Censoir and Druyes and in the environs of Tonnerre, and at Bailly and at Courson *. In Germany it was found at Thurnau and Muggendorf †; in the coralline Oolite of Hildesheim in the kingdom of Hanover ‡; in Switzerland in the terrain à chailles of Fringelli,

* Cotteau, Echin. Foss. p. 110. † Goldfuss, Petr. Germaniæ, p. 117.
‡ A. Roemer, Norddeutsches Oolithen Gebirge.

Wahlen, and Gunsberg in the canton of Soleure, and in the white corallian of Hoggerwald *.

History.—This beautiful species was long ago figured by Parkinson in his 'Organic Remains,' afterwards it was most accurately figured and described by Goldfuss in his 'Petrefacta,' and subsequently by Agassiz, Phillips, and Cotteau, in their respective works.

Cidaris propinqua, Münster. Pl. XI. fig. 6.

Syn. *Cidarites propinquus*, Münst.; Goldfuss, Petrefact. German. p. 119. t. 40. fig. 1, 2; Agassiz, Prodrom. Echin. p. 21; Echinoderm. Foss. Suisse, p. 62. t. 21. fig. 5–10; Desmoulins, Tabl. Synop. p. 328. No. 17.

Cidaris monilifera, Agassiz, Catal. Syst. Ectyp. Neoc. p. 9.

Cidaris coronata, var. *minor*, Agassiz and Desor, Cat. raisonné des Echinides; Cotteau, Echinides Foss. du Départ. de l'Yonne, p. 104.

Test thick, circular, and depressed at the poles; ambulacral areæ narrow, sinuous, and furnished with two rows of small round prominent granules; interambulacral areæ with two rows of large prominent tubercles, six in each row, raised on small mammillary eminences with smooth summits; "spines with a short neck and a thick granulated stem;" apical disc unknown.

Height $\frac{6}{10}$ths of an inch, transverse diameter 1 inch.

Description.—This Urchin resembles in many points the preceding species, but exhibits characters very distinct from it. The ambulacral areæ are extremely narrow and serpentine, having two rows of small prominent granules arranged on the margins of the areæ, with a few central microscopic ones between them about the equator. The pores are placed in rather deep winding avenues, closely and obliquely together in single pairs. The interambulacral areæ are nearly five times the width of the ambulacral, and furnished with two rows of tubercles, six in each row; they are large, prominent, slightly perforated, and nearly spherical; the mammillated eminences on which they are supported being disproportionately small, and having smooth and convex summits, unlike the crenulated summits observed in the mammæ of other Oolitic *Cidaridæ*. The specimen before us is too much injured to enable us to state whether any rudimentary sculpture surrounds the summits of the mammæ on the superior surface of the test, as is the case in the Swiss and German specimens. The areolæ are shallow and nearly of a circular form, their margins being encircled by a wreath of twelve small round prominent granules supported on little eminences, and forming a distinct beaded boundary for each tubercle. The median space down the centre of the areæ is slightly concave, and filled with

* Agassiz, Echin. Foss. Suisse.

granules of a much smaller size than those encircling the margins of the areolæ. The mouth-opening is circular and about one-half the diameter of the test at the equator; the tubercles surrounding the mouth are well developed, but smaller than those occupying the middle and upper part of the test. The apical disc is absent, but the space which it filled is of considerable diameter. The spines have not been met with in our locality.

Affinities and differences.—*C. propinqua* so nearly resembles *C. coronata*, that although it was described as a distinct species by Agassiz in his 'Echinoderm. Foss. de la Suisse,' it was afterwards grouped as var. *minor* of *C. coronata* in the 'Catalogue raisonné des Echinides*' of the same author. The test of this Urchin has unquestionably a very close resemblance to *C. coronata*, but a fact mentioned by Goldfuss should not be overlooked; he found peculiar spines associated only with *C. propinqua*, which never occurred with *C. coronata*†. The extreme narrowness of the ambulacral areæ with the two marginal rows of granules likewise distinguish it from *C. coronata*, which has six rows in the same areæ. In the absence of crenulations from the mammillary eminences on the lower part of the test, together with the bead-like granular circle around the areolæ, it resembles *C. coronata*. Not having a specimen of that species in our cabinet with which to compare the specimen before us, we are unable to pursue the comparison further.

Locality and stratigraphical range.—Whilst searching the Peagrit of Crickley Hill to find a more perfect specimen of *Goniopygus* for Mr. Baily to figure, I discovered *C. propinqua*, having only seen a defaced specimen once before from the same bed and locality, which was too much worn to be identified. We have never seen this species in any collection of Inferior Oolite fossils, and from the pains we have taken to ascertain the different species found in the Cotteswold Hills, it must be rare; it occurs in the Stonesfield slate at Eyeford, but is very rare‡. In Germany it was found by Count Münster in the Baireutheschen Jurakalke, principally in the vicinity of Streitberg§. In Switzerland it occurs in the Terrain à chailles in the environs of Besançon, Bâle, Randen, and Sirchingen||. In France it was collected by M. Cotteau from the corallian stage at Druyes, but always in the state of moulds, the specimens being of small size and having very narrow ambulacral areæ¶.

* Annales des Sciences Nat. tom. vi. 3rd series, p. 331.

† Goldfuss, Petrefact. part 1. p. 120.

‡ Sir R. Murchison, Geol. of Cheltenham, 2nd ed., by Buckman and Strickland, p. 68.

§ Goldfuss, Petrefact. German. part 1. p. 120.

|| Annales des Sciences Nat. tom. vi. 3rd series, p. 331.

¶ Echinides Foss. du Départ. de l'Yonne, p. 106.

History.—First figured and described by Goldfuss in his 'Petrefacta Germaniæ,' and afterwards by Agassiz in his 'Déscription des Echinodermes Foss. de la Suisse,' and now figured and described as a British fossil from the Inferior Oolite near Cheltenham for the first time.

Genus Hemicidaris (Agassiz).

Test subglobose, more or less flattened at the poles. Ambulacral areæ narrow and sinuous, furnished with primary tubercles on the lower fourth part of each area, which suddenly diminish into small tubercles or granules above, set more or less closely together like those in the areæ of *Cidaris*. Interambulacral areæ much larger than the ambulacral, widest at the equator of the test and narrowest at the poles; around the circumference of the mouth they are about the same breadth as those of the ambulacral areæ.

The primary tubercles of the interambulacral areæ are raised upon large prominent mammillary eminences, having a crenulated margin encircling the base of the tubercle; the equatorial plates carry the largest mammillary eminences. Pores biserial, except near the mouth, where they are triserial. Mouth large, with decagonal indentations around its circumference. Anus central, surrounded by a solid circle of ten plates which are often well preserved. The five ovarial plates are larger and perforated at their summits. The single or madreporiform plate is the largest; it has a more porous structure, and is differently sculptured from the pairs of plates. The five ocular plates are small and triangular: both ovarial and ocular plates are covered with minute granulations.

Spines of two orders: the primaries are long, cylindrical, and mostly of considerable dimensions, the secondaries are small and compressed. This genus differs from the true *Cidaris* in the bases of the ambulacral areæ supporting primary tubercles. *Hemicidaris* thus forms a type of structure intermediate between *Cidaris* and *Diadema*. In *Hemicidaris* the mouth is decagonal, in *Cidaris* it is circular.

All the species are fossil, and characterize the middle and upper stages of the oolitic rocks. Some are found in the Neocomian and in the Chalk.

Hemicidaris intermedia, Fleming.

Syn. *Cidaris papillata,* var. Park. Org. Rem. pl. 1. fig. 6. vol. iii.
Cidaris intermedia, Fleming, Brit. Animals, p. 478.
Hemicidaris crenularis, Morris, Cat. Brit. Foss. p. 53; Strickland and Buckman, Geol. of Chelt.
Hemicidaris intermedia, Forbes, Brit. Org. Rem. Decade 3. pl. 4.

Test subglobose or subconical; ambulacral areæ narrow and slightly undulated, with a double row of small perforated tubercles on the margins, and ten larger tubercles at the basis of the areæ; interambulacral areæ occupied with six or seven pairs of primary tubercles which are raised on large closely-approximated prominent mammæ, with deeply crenulated summits; mouth large and decagonal, margins deeply notched; spines long, cylindrical, and striated longitudinally, with a tumid base; apical rosette not prominent.

Great Oolite specimens: height $\frac{9}{10}$ths of an inch, transverse diameter 1 inch and $\frac{5}{10}$ths. Coral Rag specimens: height 1 inch and $\frac{4}{10}$ths, transverse diameter 1 inch and $\frac{6}{10}$ths.

Description.—The test of this Urchin has sometimes a subglobose form; in other varieties the height exceeds the breadth, and it then presents a subconical outline. The summit is slightly depressed and the base is flat. The ambulacral areæ are narrow and gently undulated; at the base or lower third we observe five pairs of moderate-sized tubercles; at the upper two-thirds the tubercles become very small and are ranged on the margins of the areæ; both the large and small tubercles are mammillated and perforated. The pores are arranged in simple pairs, but at the enlarged space around the mouth additional pairs are introduced. The interambulacral arcæ are nearly four times the width of the ambulacral, and furnished with six or seven pairs of large primary deeply perforated tubercles. The mammillary eminences on which these tubercles are placed are largely developed and form prominent projecting cones, the bases of which touch those of the adjoining cones in the same range; an undulating line of small perforated granules separates the external border of the mammillary bases from the poriferous avenues, and a double row of similar granules forms a zigzag division down the centre of the areæ. The upper and lower boundaries of the areolæ of the mammæ are confluent, whilst their outer and inner boundaries are surrounded with the granules already described.

The apical rosette is moderate in size, being about one-fourth the diameter of the test; the madreporiform plate is larger than the pairs of ovarial plates; the ocular plates are heart-shaped, and the surface of the elements of this disc is studded with small granules.

The mouth is large, being half the diameter of the test; it has a decagonal form; and the margin is deeply notched.

The spines are of two kinds: the primary ones are long, cylindrical and tapering, and grow to double the length of the diameter of the test, some of them measuring $3\frac{5}{4}$ inches in length; they are delicately grooved in the longitudinal direction, and the base is provided with a raised crenulated band, situated between

two convex smooth bands; another smaller crenulated band surrounds the rim of the socket which affords attachment to the ligaments articulating the spine with the tubercle. The secondary spines are small, needle-shaped and compressed, and striated longitudinally.

Affinities and differences.—This species approaches so near to *H. crenularis* that it was long regarded as Lamarck's species. The form and development of the spines of the two Urchins however prove them to be distinct; this circumstance shows the necessity of caution in the identification of species of Echinidæ in the absence of any of the data upon which a correct opinion can alone be formed. *H. intermedia* resembles *H. icaunensis* in its general outline, but is distinguished from that species by its more prominent tubercles, in having the ambulacral areæ more undulated and having larger tubercles at the base. These characters likewise sufficiently distinguish it from *H. alpina* and *H. granulosa.*

Locality and stratigraphical range.—One of our specimens was obtained from the spoil of Salperton Tunnel from a bed belonging to the Great Oolite; the other specimen was collected from the Bradford clay near Cirencester. We have never met with *H. intermedia* in the Inferior Oolite. This Urchin is very abundant in the Coral Rag of Calne, from whence most cabinets have been supplied. The varieties in the Great Oolite are more globular and depressed than those obtained from the Coral Rag.

History.—As it is uncertain whether we possess *H. crenularis* in our beds, it is probable that *H. intermedia* was figured and described by Martin Lister*. Our synonyms show the changes of name through which this species has passed. It has, however, been so accurately described by Prof. Forbes, and so admirably figured† in the 'Memoirs of the Geological Survey,' that we must refer to that work for further details of the species.

Hemicidaris icaunensis, Cotteau.

Syn. *Hemicidaris icaunensis,* Cotteau, Echin. Foss. t. 3. fig. 1–5. p. 56; Forbes, Geological Survey, Mem. Decade 3.

Test hemispherical, inflated and slightly depressed; ambulacral areæ with two rows of small marginal tubercles, and with three or four pairs of larger tubercles at the base; interambulacral areæ with two ranges of primary tubercles; mouth large and decagonal; margin deeply notched.

Height $\frac{8}{10}$ths of an inch, transverse diameter 1 inch and $\frac{2}{10}$ths.

Description.—This species is hemispherical and inflated at the

* Historia Animalium Angliæ, t. 7. fig. 21, 1678.

† British Organic Remains, Decade 3. pl. 4.

sides, and its transverse diameter is one-half more than its height. The interambulacral areæ are furnished with two rows of large primary tubercles; in each range there are from six to seven tubercles, which attain their greatest development at the equator of the test, and diminish in size near the anal and buccal openings. The mammillary eminences supporting the tubercles are large, prominent, and surrounded by areolæ. The tubercles are small and perforated; one row of granules separates the large tubercles from the poriferous avenues, and a double row occupies the middle of the areæ. The lateral boundaries of the areolæ are surrounded by a semicircle of granules, whilst the upper and lower boundaries of the same blend into each other.

The ambulacral areæ are narrow, slightly undulated, and furnished through nearly all their extent with a double row of small tubercles, which are not very apparent, but are larger on the sides than at the apex of the areæ; between the size of these and the three pairs of tubercles at the base a sensible difference exists. The mouth-opening is large, and is one-half the diameter of the test; it is of a decagonal form with the margin deeply notched. The apical disc is not preserved and the spines are unknown.

Affinities and differences.—The *Hemicidaris icaunensis* in its general form and characters closely resembles the *H. intermedia*; it is distinguished from the latter by having the primary tubercles of the interambulacral areæ less prominent, by the ambulacral areæ being less waved, and in having the basal tubercles much smaller. This character assimilates *H. icaunensis* to *H. Thurmanni*, but it is sufficiently distinguished from that Urchin by its greater height, less undulated ambulacra and the greater number of tubercular plates in the interambulacral areæ.

Locality and stratigraphical range.—This rare species was obtained by Mr. Lycett from the Great Oolite of Minchinhampton. M. Cotteau collected it in France from the superior beds of the Bathonian stage at Châtel-Censoir, and M. Rathier found it in the Forest marble of Châtel-Gérard, where it is likewise rare.

History.—This species was first figured and described by M. Cotteau*, and was provisionally identified by Prof. Forbes†; it is figured in plate A. fig. 9. of the 'Monograph of Great Oolite Fossils' to be published by the Palæontographical Society. The specimen that has come under our notice is so imperfect that we have followed M. Cotteau's description.

* Echinides Foss. du Département de l'Yonne, tab. iii. p. 56.

† Memoirs of the Geological Survey; Brit. Organic Remains, Decade 3. Description of plate 5.

Hemicidaris alpina, Agass. Pl. XI. fig. 3 *a*, *b*.

Syn. *Hemicidaris alpina,* Echin. Foss. Suisse, Agass. t. 18. fig. 19–22.

Test subglobose; ambulacral areæ undulated, prominent and convex, covered with small hemispherical granules closely set together; base of the areæ with four mammillated and perforated tubercles; apical disc large, convex and prominent.

Height nearly $\frac{6}{10}$ths of an inch, transverse diameter $\frac{9}{10}$ths of an inch.

Description.—The test of this beautiful species is subglobose; the ambulacral areæ are slightly undulated and of a medium size; they are prominent and convex, of an elongated conical form, and are thickly covered with small hemispherical granules without perforations or other sculpture; the marginal rows are larger and more regular. Between them are from four to six rows of smaller granules closely set together.

At the base of the areæ are four mammillated and perforated tubercles which are limited to this region. The pores are set obliquely in pairs with a smooth elevated granule between each pair, which forms a moniliform sinuous line running between the pores. The interambulacral areæ are of moderate breadth, with two rows of primary tubercles, five or six in each column. The mammillary eminences of the two central tubercles are large and prominent. Those towards the anal and oral poles are smaller; they are all crenulated at their summits; the tubercles are deeply perforated, and supported on a short stem, the hemispherical head of the tubercle not exceeding in diameter that of the stem; the areolæ around the mammæ are slightly channelled and nearly all confluent, those towards the anal pole have a circle of granules encircling the areolæ; the interareolar spaces are covered with small smooth granules similar in form and size to those occupying the ambulacral areæ. The apical disc is prominent, the ovarial plates are large, convex, and much granulated, and the ocular plates are of a proportionate size; the spines are unknown.

The mouth-opening is of moderate size, its margin being deeply notched and reflexed as in *H. intermedia*; the pores are disposed in simple pairs all the length of the poriferous avenues, but are arranged in double files around the border of the oral aperture in such a manner as to occupy the free space in the ambulacral areæ, resulting from the contraction of the interambulacral areæ in this region.

Affinities and differences.—Our specimen is smaller in size than the one figured by Agassiz from the Calcaire de Saanen. The ambulacra are more prominent and convex than those of the Swiss specimen; the rows of marginal granules are not so pro-

portionately large nor are the basal tubercles so numerous as those delineated in Agassiz's figure. We consider our Urchin, however, merely as a variety of the Swiss species, for which we propose the name var. *granularis*. This beautiful species is easily distinguished from its congeners by the structure of the ambulacral arcæ, which are convex, prominent, and thickly covered with small close-set granulations unlike any other species of *Hemicidaris* yet known.

Locality and stratigraphical range.—This species was collected from the Bradford clay of Pickwick, Wilts; a valve of *Ter. digona* was attached to the test, and it is adherent to *Ter. concinna*. Plates of this Urchin have been found in the same stratum at the Tetbury Road Station of the Great Western Railway. Mr. Lowe of Chippenham has found it in the Forest marble of Wilts, but it is a rare species.

History.—First figured and described by Agassiz in the 'Description des Echinodermes Fossiles de la Suisse,' afterwards identified in the British Museum collection by Mr. S. P. Woodward, and recorded by Prof. Forbes in Decade 3. of his 'Memoirs of the Geological Survey,' and now described as a British species for the first time.

Hemicidaris granulosa, Wright. Pl. XI. fig. 4 *a*, *b*, *c*.

Test spheroidal, depressed; ambulacral areæ straight, with two rows of prominent defined granules, the three inferior pair only being perforated and raised upon crenulated mammillary eminences; interambulacral areæ with from two to three pairs of primary tubercles, the superior part of the areæ being occupied with warty granules; apical rosette formed of large petaloidal plates.

Height $\frac{7}{10}$ths of an inch, transverse diameter 1 inch and $\frac{2}{10}$ths.

Description.—This beautiful Urchin constitutes a well-marked species; the double row of prominent wart-like granules on the ambulacral areæ, which are neither perforated nor raised on eminences, serving as a good diagnostic character. The base of the area is enlarged to give space for the three pairs of crenulated and perforated tubercles found in this region in all the species of *Hemicidaris*. The upper part of the areæ is occupied with from 10–12 pairs of warty granules, which are smooth, deformed, and set regularly in rows alternating with each other; the intervening surface of the ambulacral plates being occupied with small ill-defined scattered granulations. The pores are disposed in slightly oblique pairs, with a raised eminence between them; at the wide basal region of the avenues they fall into triple oblique pairs.

The interambulacral areæ are twice and a half the diameter of the ambulacral; in each column there are from six to seven plates, the three or four inferior of which support moderate-sized mammillary eminences with crenulated summits, from the centre of which a large prominent deeply perforate tubercle rises. The areolæ are smooth and gently inclined, and around their circumference fifteen small granules are set. The three superior plates are destitute of mammillary eminences, and in lieu thereof have clusters of granules on each plate similar to those occupying the ambulacral areæ. There are from two to five such granules protruding from the upper surface of the test; they are arranged in pairs, or form triangular, quadrangular or pentagonal figures. The apical rosette is well developed; the *ovarial* plates are large and marked with a depression near their centre, and their internal borders are slightly raised. The *madreporiform* plate is larger than the pairs of plates, and its centre is occupied with a porous structure. The *ocular* plates are large and heart-shaped, with a depression down the centre of each plate. In the specimen before me the plates of the apical rosette are devoid of other sculpture.

The base is flat, the mouth large and decagonal, the opening being more than half the diameter of the test at its equator.

The spines are unknown.

Affinities and differences.—This Urchin differs from *H. intermedia* in the absence of tubercles from the upper part of the interambulacral areæ, in the form and size of the ovarial and ocular plates, and in the form and structure of the granules covering the ambulacral areæ. It is distinguished from *H. alpina* by the absence of the close-set granulations covering the convex ambulacra of that Urchin. It has some resemblance to *H. icaunensis*, but is distinguished from it by the small number of its primary tubercles, and the warty figures which take the place of the tubercles on the upper surface of the test.

Locality and stratigraphical range.—From the Inferior Oolite of Dundry. Imperfect specimens, probably belonging to this species, have been collected from the upper beds of Leckhampton.

Hemicidaris confluens, M'Coy.

Syn. *Hemicidaris confluens*, M'Coy, Annals of Nat. Hist. vol. ii. New Series, p. 411.

Test spheroidal, much-depressed; ambulacral areæ slightly convex and nearly straight, with two alternate marginal rows of small microscopic mammillated and perforated tubercles, four pairs of larger tubercles at the base; intermediate surface covered with small close-set granulations; interambulacral areæ with three pairs of large tubercles at the middle, four

small tubercles at the base, and six rudimentary tubercles at the apex of the areæ; mouth moderate and decagonal.

Height $\frac{9}{20}$ths of an inch, transverse diameter $\frac{9}{10}$ths of an inch.

Description.—The spheroidal test of this Urchin is much depressed at the anal pole and flattened at the base. The ambulacral areæ are nearly straight and of a tolerably uniform width throughout, and furnished with two rows of small, quite microscopic, but nevertheless mammillated and perforated tubercles, about fourteen in each row, disposed alternately on the margins of the areæ, and increasing slightly in size towards the basal angle. The base of the areæ has four pairs of larger tubercles as in the other species of this genus. The interambulacral areæ are nearly three times the width of the ambulacral, and furnished with two rows of tubercles from 9–10 in each row, the three pairs at the equator of the test alone attaining their full development; those at the base being of a secondary size, whilst those on the upper part of the areæ are disproportionately small and even rudimentary. The upper surface of the test is covered with small close-set granulations, in the midst of which the rudimentary tubercles rise at distant intervals apart. The mammillated eminences of the six large tubercles are surrounded by well-defined areolæ, which are confluent at their upper and lower margins; but down the centre of the areæ two or four rows of granules, and at the lateral borders thereof one or two rows of granules descend, which form lateral wreaths surrounding the side margins of the areolæ: these marginal granules are larger and more uniform in their arrangement than those occupying other parts of the surface of the test.

The mouth-opening, of a decagonal form, is one-half the diameter of the body, with deep marginal notches dividing its circumference into ten nearly equal lobes, those of the ambulacral areæ being the largest.

The apical disc is either absent or concealed in the specimens before me, and the spines are unknown.

Affinities and differences.—H. confluens resembles *H. Thurmanni*, Ag., in its depressed form and in the small number of the primary tubercles on the interambulacral areæ; it is distinguished from that species in the partial absence of the circle of granules which entirely surround the tubercles in *H. Thurmanni*, and in the rudimentary condition of those occupying the upper surface of the test. The ambulacral areæ are nearly straight in *H. confluens*, and much undulated in *H. Thurmanni*. This Urchin has many points of affinity with *Acrosaleniæ*, but our ignorance of the apical disc leaves a doubt in our mind whether it may not belong to that genus. Until specimens with the disc preserved are found, that doubt cannot be removed.

Locality and stratigraphical range.—This species was collected by Mr. Lycett from the planking beds of the Great Oolite at Minchinhampton, and we have received several specimens from the same stratum at Kiddington (Oxfordshire).

Hemicidaris pustulosa, Forbes.

Memoir of Palæontograph. Soc., Forbes, plate A. fig. 8, Great Oolite Fossils.

We have not seen *Hemicidaris pustulosa* figured by Professor Forbes in the above memoir; its nearest ally, it is stated, "is *Hemicidaris diademata*, Agass., which it resembles in the sudden diminution and very small size of the uppermost interambulacral tubercles, but differs in having the sutural granulated space of the interambulacral areas very wide*."

The Salenians†, Gray.

This group is composed of small Urchins resembling *Hemicidaris*; they are distinguished from that genus, however, by the number, structure, and mode of arrangement of the plates forming the apical disc, which is composed of five ovarial, five ocular, and a supra-anal plate. The ambulacral areæ are narrow, carrying secondary tubercles like *Hemicidaris*. The pores are disposed in distinct poriferous avenues in single pairs. The interambulacral areæ are wide, and their plates support primary tubercles raised on mammillary eminences. We divide the Salenians into two groups:—

In the first group the tubercles are not perforated; they form the genera *Salenia*, *Peltastes*, and *Goniophorus*, which are limited to the rocks of the Cretaceous period.

In the second group the tubercles are perforated, forming the genus *Acrosalenia*, the species of which are distributed throughout the Jurassic strata.

Genus Acrosalenia, Agass.

Test small, more or less depressed; anal pole surrounded by a well-developed circular disc, composed of five ovarial and five ocular plates, with a central *supra-anal plate*, composed of one or more elements. The anal opening is situated at one side of the supra-anal plate, and is therefore eccentrical. The ambulacral areæ are narrow, and support a double row of from ten to twelve small perforated tubercles set on crenulated mammæ.

* Memoirs of Geological Survey, Prof. Forbes, Decade 3.

† The group of Salenians is composed of five genera: *Salenia*, Gray; *Peltastes*, Agass.; *Goniophorus*, Agass.; *Acrosalenia*, Agass.; *Goniopygus*, Agass.

The interambulacral areæ are nearly three times the width of the ambulacral areæ, and support two rows of from six to eight large perforated tubercles raised upon crenulated mammillary eminences; the base is flat, the mouth large, decagonal and notched, and the margin reflexed. The apices of the notches point to the centres of the columns of the interambulacral plates.

Acrosalenia hemicidaroides, Wright, n. s. Pl. XI. fig. 1 *a, b, c, d.*

Test hemispherical, considerably depressed; ambulacral areæ with two ranges of from fourteen to sixteen small perforated tubercles, gradually decreasing in size from the base to the apex; interambulacral areæ with two ranges of primary tubercles, eight in each range. The supra-anal plate is composed of several elements; the anus is situated before and to the left side; the surface of the ovarial, ocular, and supra-anal plates is studded with small granulations; primary spines long, tapering, smooth and slightly compressed; secondary spines small and needle-shaped; mouth large and decagonal; margin reflexed.

Height $\frac{7}{10}$ths of an inch, transverse diameter 1 inch and $\frac{1}{10}$th. One large specimen measures 1 inch and $\frac{3}{10}$ths in diameter, but the proportional height cannot be ascertained, as its base is crushed.

Description.—Test spheroidal, depressed; ambulacral areæ slightly sinuous, nearly uniform in breadth, tapering towards both poles, and supporting two rows of secondary mammillated perforated tubercles, which are largest at the inferior third of the area, diminishing in size as they approach the mouth and the anus. The tubercles, from fourteen to sixteen in number in each row, are situated alternately on the margins of the area; a zigzag line of granulations, with lateral branches passing down the centre of the area, separates the tubercles from each other. The poriferous avenues consist of about forty-five pairs of pores set obliquely in a single file. The interambulacral areæ are three times the breadth of the ambulacral; each area is composed of two columns. There are eight plates in each column, and each plate supports a large smooth mammillated eminence surmounted by a tubercle, which occupies the greater part of the plate; it is of a conical form, and is encircled by a concave smooth areola. The summits of the mammæ are sculptured on their margins with eleven crenulations, in the centre of which a deeply perforated tubercle rises, with a rather depressed articular surface. In some specimens the areolæ of the mammæ are confluent, in others they are separated by a row of small granules. The external and internal margins of the plates are furnished with rows

of small granulations, with still smaller granules here and there interspersed; on the external side of each plate there are nine granulations, which, with those of the adjoining plates, form a sinuous granulated line which defines the internal boundary of the poriferous avenues. The internal row of granulations, with those of the opposite and adjoining plates, form a double granulated zigzag space, occupying the centre of the areæ, and forming an elevated ridge which serves to separate the two ranges of primary tubercles from each other.

The mouth is large and decagonal, and is one-half the diameter of the test. The margin is deeply notched with ten indentations. The divisions of the circumference are not equal, as the arch over the ambulacral is one-half greater than the arch over the interambulacral areæ.

The apical disc is greatly developed, occupying more than one-third the diameter of the test; it is of a pentagonal form, the left anterior angle being more developed than the right. The madreporiform plate is large, and divided into a posterior porous and an anterior non-porous segment. The posterior pair of ovarial plates are likewise large, the anterior pair are small and imperfectly developed; the left plate is rudimentary, in consequence of the anal opening being eccentric and situated before and towards the left side; the supra-anal plate is in general of a pentagonal form, and composed of from four to six elements united together and set round the posterior border of the anal opening. The ocular plates are triangular and well-developed; all the plates of the apical disc are studded with small granules. This species belongs to Agassiz's first division of the Salenians which have the sur-anal plate and the oviductal apparatus situated before the madreporiform plate. The primary spines (fig. 1 *d*) are long, tapering, and slightly compressed, so that a transverse section of one of them forms an ellipsis in the specimen before me. They are in length about twice the diameter of the test. The body of the spine is smooth throughout; the base is encircled with a prominent elevated ring of small oblong closely-set granulations; a smaller circle of larger crenulations surrounding the margin of the concave articulating surface. The secondary spines articulating with the tubercles of the ambulacral areæ resemble the primaries in miniature, some of them measuring $\frac{5}{10}$ths of an inch in length.

The dental apparatus is well-developed. The teeth are strong, triangular, and slightly curved towards the point.

Affinities and differences.—Acrosalenia hemicidaroides is distinguished from its congeners by its size, the number and regularity of the primary tubercles, the compound structure of the supra-anal plate, and the granular surface of the apical disc. This Urchin so much resembles a *Hemicidaris* in the form of the

test, the structure of the ambulacra and poriferous avenues, that it was not until we had obtained specimens with the apical disc preserved that we were satisfied of its being an *Acrosalenia*, of which it certainly forms the finest species. The genera *Hemicidaris* and *Acrosalenia* have so many characters in *common*, which are almost always well-preserved, and so few that are *special*, and which are for the most part either broken or absent, that it is difficult to decide upon the genus unless the apical disc is more or less preserved; it is for this reason we conjecture that so few *Acrosaleniæ* have been hitherto catalogued from the Oolites, most of the species having been erroneously referred to other genera. The development of from four to six larger mammillated tubercles at the base of the ambulacral areæ is a good character for *Hemicidaris*. In *A. hemicidaroides* the tubercles in this region are well developed, but are not so well defined as in *Hemicidaris*. When doubts exist, they can only be solved by the discovery of the apical disc with its supra-anal plate.

Locality and stratigraphical range.—I have collected this beautiful Urchin from the upper beds of the Inferior Oolite at Leckhampton, and the Rev. P. B. Brodie found it with its spines attached in the same zone at Selsley Hill. It is found in the planking beds of the Great Oolite at Minchinhampton, and in the Cornbrash near Chippenham. Several fine specimens with the spines attached to the test were obtained from the Forest marble near Malmsbury in Wilts, which are now in the British Museum and the Museum of Economic Geology, and several private cabinets. We have the same species from Kiddington, Oxfordshire, in slabs of Great Oolite. From these facts we infer that this large *Acrosalenian* had not only a considerable stratigraphical range, but likewise that the species was very abundant.

Acrosalenia Lycetti, Wright, n. s. Pl. XI. fig. 2 *a*, *b*, *c*, *d*.

Test hemispherical, depressed, circumference subpentagonal; ambulacral areæ prominent, having a double series of small tubercles; interambulacral areæ with two ranges of large tubercles; mammillary eminences of both areæ conical and projecting; tubercles of the interambulacral areæ disproportionately small.

Height half an inch, transverse diameter 1 inch.

Description.—This Urchin resembles *A. hemicidaroides* in many of its characters, but presents others which justify its separation from that species. The ambulacral areæ are straight, prominent, and furnished with a double row of small well-developed tubercles, about twelve in each row; a zigzag line of small granules descends down the centre of the areæ, sending out lateral

branches which inclose the areolæ of the tubercles for about two-thirds of their circumference, leaving the areolæ open to the poriferous avenues. The interambulacral areæ are nearly three times the width of the ambulacral, and possess a double range of primary tubercles from seven to eight in each range. The mammillary eminences supporting them are very prominent, and are surrounded by an elliptical areola. The summits of the mammæ are sculptured with about ten crenulations. The tubercles are disproportionately small when compared with the development of the mammæ supporting them; the two ranges of tubercles are separated by four rows of granulations which form zigzag granular bands descending down the centre of the areæ; similar bands of granulations bound the external borders of the interambulacra, and separate the ranges of the principal tubercles from the poriferous avenues; the upper and lower borders of the areolæ are confluent, but the other parts of their circumference are surrounded by a wreath of granules. The mammillary eminences and tubercles are largest at the equator, gradually diminishing as they approach the oral and anal poles. The pores are large and disposed obliquely in simple pairs. The mouth-opening is large and decagonal, the marginal notches being of moderate depth. The apical disc is absent in all the specimens we have found; it is therefore impossible to state whether the anal opening was situated before or behind the single madreporiform plate.

Affinities and differences.—This species is distinguished from *A. hemicidaroides* in having the areolæ more excavated and elliptical. The granules occupying the intertubercular spaces are smaller and more numerous. The tubercles of the interambulacra are disproportionately small when compared with the development of their mammæ; the circumference has in general a subpentagonal outline, from the prominence of the ambulacral areæ, the double row of tubercles on which is more fully developed than in *A. hemicidaroides*. These differences between the tests of our two species although inconsiderable are nevertheless connected with others, which although not seen may be inferred, as the differences in the size and form of the primary and secondary spines belonging to the tubercles of both areæ leave no doubt on our mind that *A. Lycetti* is distinct from *A. hemicidaroides*, and we know of no other species among its congeners for which it could be mistaken. A granulated spine, and of which we give a figure (2 *d*), found frequently in the same beds with *A. Lycetti*, and probably belonging to this species, if proved to be such, would form an important specific character.

Locality and stratigraphical range.—We collected this Urchin from the lower ferruginous beds, Pea-grit, of Crickley Hill, and have found it in the same stratum at Leckhampton, Cleeve, and

Brockhampton quarries. The specimens are in general much crushed, and the apical disc is always absent.

The two specimens which have preserved their form and served for the foregoing description were only obtained within the last few days; all those previously collected having been too much injured to serve for minute observation.

I dedicate this species to my friend John Lycett, Esq., one of the learned authors of a monograph of the Mollusca from the Great Oolite.

Acrosalenia spinosa, Agassiz. Pl. XII. fig. 3 *a, b, c, d.*

Acrosalenia spinosa, Agassiz, Echin. de la Suisse, 2nd part, t. 18. fig. 1–5. p. 39; Cotteau, Echin. Foss. du Département de l'Yonne, t. 3. fig. 6–11.

Test subpentagonal, depressed; a double row of small tubercles occupies the ambulacra, and a double range of large mammillated tubercles the interambulacral areæ; the ovarial disc is large, the madreporiform plate rudimentary, the anal opening behind the supra-anal plate; mouth decagonal, margin deeply incised.

Height $\frac{5}{10}$ths of an inch, transverse diameter $\frac{12}{20}$ths of an inch.

Description.—The test of this beautiful little Urchin has a subpentagonal form arising from the convexity of the ambulacral areæ, which converge in straight lines from the base to the summit, and are furnished with two ranges of from ten to twelve very small tubercles, which, although microscopic, are nevertheless mammillated and perforated. The intertubercular spaces are covered with small granules which form circles around the tubercles. The pores are disposed obliquely in simple pairs, forming a single rectilineal file on each side of the areæ. The interambulacral areæ are twice the width of the ambulacral, and ornamented with a double range of primary tubercles, eight in each range. The two inferior tubercles are small, the two or three succeeding ones are very large, whilst those on the upper part of the test suddenly diminish in size and gradually become dwarfed as they approach the anal disc: they are all crenulated and perforated. The primary tubercles occupying the equator of the test are seated upon large prominent mammillary eminences, surrounded by deeply grooved elliptical areolæ, and encircled by a wreath of small granules. The intertubercular surface on the upper part of the test is studded with very fine granules. The apical rosette, formed of ovarial, ocular, and sur-anal plates, is admirably preserved in the specimens before us; it is large and of a pentagonal form (fig. 3 *d*). The two anterior pairs of ovarial plates are nearly of the same size, the posterior pair being notched to form the basal angles of the triangular anal opening; the sur-anal plate occupying the centre of the rosette is small, single and pentagonal; the single or madre-

poriform plate is rudimentary, to make space for the apex of the anal opening. By this arrangement it is evident that the anus is eccentrical and situated behind the sur-anal plate; its opening is in a great measure formed by the imperfect development of the madreporiform plate, a condition the opposite to that existing in *A. hemicidaroides*, where the anus is situated in front of the sur-anal plate, and is excavated at the expense of the left anterior ovarial plate. The four ovarial and sur-anal plates are adorned with a delicate sculpture which occupies their centres; the ocular plates are small; the three anterior are inserted between the prominent angles of the ovarials, whilst the two posterior lying between the madreporiform plate and the posterior pair of ovarials form the lateral walls of the anal opening; all the plates are finely granulated.

The mouth is large, its circumference being divided into ten nearly equal lobes, and the margin is much reflexed.

Affinities and differences.—*Acrosalenia spinosa* is distinguished from its congeners by its subpentagonal form, the volume of the mammillary eminences of the primary tubercles at its equator, and the sudden smallness of those occupying the upper part of the test, the position of the anal opening behind the sur-anal plate, and the rudimentary condition of the madreporiform plate.

Locality and stratigraphical range.—I collected this Urchin from the yellow clay resting on the Stonesfield slate at Sevenhampton with *Anabacia orbulites, Pecten vagans, Ostrea acuminata*, and other Great Oolite shells. Likewise from the Cornbrash near Chippenham, Wilts, where it is very abundant. The specimens from both localities are as perfect as recent *Echini*.

Many of the Cornbrash specimens are attached to *Avicula echinata*. In Switzerland *A. spinosa* was collected from marls containing *Ostrea acuminata* in the Canton of Soleure. It is found in great abundance in France in the Great Oolite of Caen, and has been collected by M. Cotteau from the upper beds of the Bathonian stage in the environs of Châtel-Censoir.

History.—This species was figured and described for the first time by M. Agassiz in his 'Echinoderm. Fossiles de la Suisse,' and entered in his 'Catalogue raisonné des Echinides.' It has been figured and described by M. Cotteau from specimens obtained in the department of l'Yonne. It is catalogued by Mr. M'Coy as a Minchinhampton species from the Great Oolite, and is now described from British specimens for the first time.

Genus Goniopygus, Agassiz.

Test circular, subconical; apical disc very solid with an angular circumference, composed of ten plates; sur-anal plate absent; mouth large; tubercles imperforate without crenulations at their base; pores disposed in simple pairs throughout.

Goniopygus (?) *perforatus*, Wright, n. s. Pl. XIII. fig. 5 *a*, *b*.

Test spheroidal, depressed; ambulacral areæ with two rows of small tubercles; interambulacral areæ with two rows of nearly equal-sized primary tubercles, each surrounded by a circle of granules; tubercles perforated.

Height $\frac{3}{10}$ths of an inch, transverse diameter $\frac{6}{10}$ths of an inch.

Description.—The ambulacral areæ of this little anomalous Urchin carry small marginal tubercles increasing in size towards the base of the areæ, and having a few granules interspersed between them. The interambulacral areæ are about twice and a half the width of the ambulacral, and furnished with two rows of tubercles from seven to eight in each row. The tubercles are raised on mammillated eminences which are destitute of crenulations; the summit of the tubercles is slightly perforated, they detach themselves in a well-defined manner from the surface of the test and are very uniform in size, and each mamma is encircled by a distinct wreath of small granules. There are a few other granules studding the plates besides those forming the boundary circles of the areolæ. The apical disc is absent; the mouth is large and deeply notched.

Affinities and differences.—I have placed this Urchin provisionally in the genus *Goniopygus*, as it comes nearer to the characters of that form than any other. Agassiz states in his Catalogue that the tubercles are imperforate, but this character is not alluded to in his 'Echin. Foss.' The absence of crenulations from the mammæ, the nearly uniform size of the tubercles, the distinctness with which they stand out from the test, and a fragment of the angular apical disc *in situ*, seem to justify the supposition of its being *Goniopygus*; but the perforations in the tubercles make the exception, and suggest the query whether the absence of perforations is a generic or only a sectional character. The specimens before me, the only three yet found, are so imperfect, that I write with much reserve regarding them; they may perhaps prove to be the young tests of *Pedina*, in which we have observed that the pores change from simple pairs to triple oblique pairs with age, and the crenulations of the mammæ can scarcely be seen.

Locality.—I collected these Urchins from the Pea-grit of Crickley Hill with *Acrosalenia Lycetti* and small Bryozoan polypifera.

The Echinidæ*

Have a thin test, and are distinguished from the Cidaridæ and

* The group of *Echinidæ* includes twenty-three genera: *Astropyga*, Gray; *Diadema*, Gray; *Hemidiadema*, Agass.; *Cyphosoma*, Agass.; *Echinocidaris*,

Salenians by having numerous nearly equal-sized tubercles upon the ambulacral and interambulacral areæ. The pores are differently arranged in the avenues in the different genera; the apical disc consists of five ovarial and five ocular plates.

Genus Diadema, Gray.

Test thin, of a circular or pentagonal form, more or less depressed, supporting perforated tubercles raised on mammillary eminences with slightly crenulated summits. The ambulacral areæ are wide, straight, and well developed; each area has two rows of primary tubercles nearly as large as those occupying the interambulacral areæ. The pores are set in pairs, uniformly superimposed on each other, with one or two exceptions, where they fall into double files. The interambulacral areæ have two rows of primary tubercles, and sometimes ranges of secondary tubercles placed external to them. The mouth is large and decagonal, with shallow marginal notches. The five ovarial plates have an elongated hexagonal form; the madreporiform is larger than the pairs of plates; the five ocular plates are small and triangular, and are lodged at the summits of the ambulacra between the re-entrant angles formed by the ovarial plates. The spines are long, slender, and subulate, and of a very uniform size throughout.

Diadema depressum, Agassiz. Pl. XII. fig. 2 *a, b, c, d.*

Syn. *Diadema depressum,* Agassiz and Desor, Catalogue raisonné des Echinides, Ann. des Sciences Nat. 1846; Cotteau, Etudes sur Echinides Fossiles, p. 43. t. 2.

Test pentagonal, depressed; ambulacral areæ convex and prominent; interambulacral areæ flattened; two rows of nearly equal-sized primary tubercles in both areæ; secondary tubercles absent or rudimentary; mouth large and slightly decagonal.

Height $\frac{5}{10}$ths of an inch, breadth 1 inch and $\frac{1}{10}$th.

Description.—The ambulacral areæ of this Urchin are rather more than one-half the breadth of the interambulacral areæ, and have from ten to twelve pairs of well-developed primary tubercles separated by a zigzag line of small granulations. The interambulacral areæ are nearly of a uniform breadth throughout; there are about ten pairs of tubercles in each area; in consequence of

Desmoulins; *Echinopsis,* Agass.; *Arbacia,* Gray; *Eucosmus,* Agass.; *Cœlopleurus,* Agass.; *Codiopsis,* Agass.; *Mespilia,* Desor; *Microcyphus,* Agass.; *Salmacis,* Agass.; *Temnopleurus,* Agass.; *Glypticus,* Agass.; *Polycyphus,* Agass.; *Amblypneustes,* Agass.; *Boletia,* Desor; *Tripneustes,* Agass.; *Holopneustes,* Agass.; *Echinus,* Linn.; *Pedina,* Agass.; *Heliocidaris,* Desmoulins.

these segments of the test being double the width of the ambulacral, the tubercles stand more apart. The tubercles of both areæ are nearly uniform in size, they have a smooth base with a finely crenulated summit, and are perforated; there are no secondary tubercles, but the intertubercular spaces are covered with small granulations, which are closely set together on the surface of the plates; three or four of these at the base of the areæ are perforated. The mammillary eminences of both areæ are surrounded by smooth areolæ, which are nearly all confluent. The ambulacral areæ become rapidly contracted towards the vertex, whilst the interambulacral areæ maintain their breadth, so that the space between the rows of primary tubercles is very uniform in width throughout. The intertubercular spaces, with the exception of the internal border of the four superior interambulacral plates, are covered with small close-set granulations of different sizes, which form semicircles around the areolæ, and zigzag lines down the centres of the areæ. The pores consist of thirty-six pair in each avenue superimposed in a single file; in the wide space of the avenues around the mouth they form double or triple rows. The mouth is large and decagonal; the notches are slight, and the borders are reflexed at the angles; the apical disc is unknown; the spines are small, subulate, and delicately striated longitudinally (fig. 2 *d*).

Affinities and differences.—This Urchin resembles *D. æquale*, Agass., but differs from it in the absence of secondary tubercles in the interambulacral areæ: by its pentagonal form it resembles *D. subangulare*, but is distinguished from that species in having the pores arranged in a single file, whereas in *D. subangulare*, from the equator to the apical disc, the pores fall into double files. The tubercles are likewise smaller and more deeply perforated; it belongs moreover to a lower zone of the Oolitic group, *D. subangulare* being a characteristic Urchin of the Coral Rag of Wilts and the "Terrain à chailles" of Switzerland and Germany*. Like *D. subangulare*, *D. depressum* possesses a pentagonal form, a peculiarity depending on the prominence of the ambulacral areæ, and common to several species of this genus.

Locality and stratigraphical range.—This Urchin is common in the lower ferruginous beds of the Inferior Oolite, the Pea-grit of Crickley, Leckhampton and Dundry Hills; I have collected it from the Great Oolite at Minchinhampton and from the Bradford clay at Tetbury road station; the latter were extremely small. The specimens are in general much crushed; the anal disc is always broken, and the spines are sometimes adherent to the test. It has been collected by M. D'Orbigny in the Inferior oolite of

* Goldfuss, Petrefacta Germaniæ; and Agassiz, Echinodermes Fossiles de la Suisse.

Saint Honorine Ranville, where it is abundant. It has been obtained by M. Cotteau from the ferruginous oolite, from Tour-du-Pré, near Avallon, Département de l'Yonne, which bed lies upon the Calcaire à entroques, the true equivalent of the Dundry, Cotteswold and Dorsetshire beds of the Inferior Oolite.

History.—The *D. depressum* was first mentioned in the 'Catalogue raisonné des Echinides' by Agassiz and Desor, but was neither figured nor described by them. This however has been done by M. Cotteau in his 'Etudes sur les Echinides Fossiles,' and is now figured and described from the English Oolites for the first time. In both countries it appears to characterize beds belonging to the same geological horizon.

Diadema subangulare, Agass.

Syn. *Cidarites subangularis,* Goldfuss, Petref. t. 40. f. 3; Rœmer, Verstein. t. 1. fig. 20.
Diadema subangulare, Agassiz, Echin. Foss. t. 17. fig. 21–25. p. 19.

Test subpentagonal, depressed; interambulacral areæ with primary and secondary tubercles; upper part of the poriferous avenues with a double series of pores.

Height $\frac{9}{20}$ths of an inch, transverse diameter 1 inch and $\frac{2}{10}$ths.

Description.—The test of this Urchin has a depressed and pentagonal form arising from the prominence and development of the ambulacral areæ, which are narrow and contracted above and furnished with ten pairs of primary tubercles. The interambulacral areæ are nearly twice as wide as the ambulacral, and are adorned with two rows of primary tubercles from ten to eleven in each row, and two rows of secondary tubercles arranged on the sides of the primaries, but irregular both as regards their number and size. Secondary tubercles are absent in the ambulacral areæ. The tubercles of both areæ are proportionally large and raised upon inconsiderable mammillary eminences with delicately crenulated summits; the mammæ are surrounded by elliptical areolæ, and round two-thirds of their circumference small granules are disposed in circles; although the tubercles are large and spherical, the perforations are small and of inconsiderable depth. Down the centres of both areæ numerous small granulations occupy the intertubercular surface of the plates, and similar granular bands descend down the external margins of the interambulacral areæ; but the distinctive character of this Urchin resides in the structure of the poriferous avenues, which, instead of forming, as in other *Diademata,* a *single row* of pores from the base to the apex, from the equator to the apical disc they form *double rows of pores disposed in oblique lines.*

The mouth is large and decagonal, but the marginal notches

are not deep. None of the specimens that we have seen possess the apical disc, but the vacant space left by the absence of the ovarial and ocular plates proves that this part of the test was well developed.

Affinities and differences.—In its pentagonal form it is allied to *D. depressum*, but its secondary tubercles and double file of pores form a good diagnosis between *D. subangulare* and other species of the same genus.

Locality and stratigraphical range.—We know this species only from the Coral Rag of Wilts and Oxford; in Germany it is found in the same stages at Thurnau and Muggendorf; and in Switzerland it is obtained from the "Terrain à chailles" of the valley of the Birse, of Blochmont and of Weissenstein.

History.—First figured by Goldfuss, afterwards more accurately described and figured in detail by M. Agassiz, and now described as a British species for the first time; the specimens previously catalogued under this name having been *D. depressum* and not *D. subangulare.*

Diadema pseudo-diadema, Agass. Pl. XII. fig. 1 *a, b, c.*

Syn. *Cidarites pseudo-diadema,* Lamarck, Syst. Anim. sans Vert. tom. iii. p. 385.
Diadema Lamarckii, Desmoulins, Tabl. Synopt. p. 316. No. 18.
Diadema pseudo-diadema, Agassiz, Echin. Foss. t. 17. fig. 49–53.

Test hemispherical, depressed; interambulacral areæ with primary and secondary tubercles; ambulacral areæ with primary tubercles and a few scattered rudimentary ones. Mouth large and decagonal; margin deeply notched; apical disc large; spines long and needle-shaped.

Height 1 inch and $\frac{5}{10}$ths, transverse diameter 2 inches and $\frac{4}{10}$ths.

Description.—This fine species has a hemispherical form, much depressed at the anal pole and flattened at the base. The ambulacral areæ are straight and well developed, and furnished with two rows of primary tubercles from 18–20 in each row; between these a zigzag line of small secondary tubercles extends two-thirds up the areæ; the poriferous avenues are not well defined; the pores are disposed in pairs; between each pair of holes there are elevated smooth tubercles forming a range of small bead-like bodies which define the limits of the areæ; at the base the pores fall into double and triple files.

The interambulacral areæ are more than twice the width of the ambulacral, and are furnished with two rows of large primary crenulated and perforated tubercles, and several rows of secondary tubercles likewise crenulated and perforated; down the

centre of the areæ two rows of secondary tubercles are arranged which separate the principal ranges from each other, and like rows of secondary tubercles separate the principal tubercles from the ambulacral areæ. These secondary tubercles are very irregular as to size and arrangement, and are in general best developed at the base and equator of the test; besides the primary and secondary tubercles, the surface is studded with small granulations. The mouth-opening is large and decagonal, and its margin is divided by deep notches. The lobes which correspond to the ambulacral areæ are twice as large as those corresponding to the interambulacral areæ. The apical disc is broken in the specimen before me. According to Agassiz the oviductal apparatus is generally very apparent. The ovarial plates are large and pentagonal; their summit forms a prominent angle which advances into the interambulacral areæ. The madreporiform plate is larger than the pairs of plates, and like them is perforated and finely granulated. The ocular plates are very small and inserted between the angles of the ovarials and dovetailed with the apex of the ambulacra. The anal opening is large and of a circular form. The spines are long, needle-shaped, and finely striated longitudinally.

Affinities and differences.—The size of this species, the arrangement of the secondary tubercles, and the structure of the poriferous avenues form a group of characters by which it is readily distinguished from its congeners.

Locality and stratigraphical range.—The specimen before me was obtained from the Coral Rag of Wiltshire or Oxfordshire; it is found in the Corallian stage of Besançon, canton of Soleure, in Switzerland, and in the Coral Rag of Angoulin, near Rochelle, in France.

History.—Figured and accurately described for the first time by M. Agassiz in his 'Echin. Foss.,' and now first figured and registered as a British fossil.

Genus Pedina, Agassiz.

Test thin, circular and depressed; primary tubercles very small, but still perforated and crenulated like those of *Diadema*. Pores arranged in triple oblique pairs as in the genus *Echinus*. Mouth small, slightly decagonal; margin not much notched. The ovarial disc not prominent; the surface of the test comparatively smooth when compared with the other genera of the *Echinidæ*. The ambulacral areæ have two ranges of tubercles, and the interambulacral areæ have two ranges of primary, and one or more rows, more or less complete, of secondary tubercles, situated at the external and internal sides of the primaries. This

genus is extinct, and the species are found in the Oolitic and Cretaceous rocks.

Pedina rotata, Agassiz.

Syn. *Pedina rotata*, Agassiz, Echin. Foss. de la Suisse, pl. 15. fig. 4–6. p. 36.

Test hemispherical, depressed; ambulacral areæ with two marginal rows of small tubercles; interambulacral areæ with two ranges of primary tubercles and a few secondary tubercles; mouth small; margin slightly notched and divided into ten nearly equal-sized lobes.

Height $\frac{8}{10}$ths of an inch, transverse diameter 1 inch and $\frac{4}{10}$ths.

Description.—The test of this Urchin is circular; in some specimens a fullness of the ambulacral areæ gives it a slightly-subpentagonal outline, and it is depressed at both poles. The ambulacral areæ have two rows of small tubercles disposed on the external border of the areæ, between which small granules are arranged with less regularity. The interambulacral areæ are twice and a half the width of the ambulacral, and furnished with a double range of primary tubercles extending from the mouth to the ovarial plates; two ranges of secondary tubercles, not very regular however in their arrangement, extend from the mouth to near the middle of the areæ. The tubercles of both classes are very small in size, but perforated and crenulated on the surface of the test a number of small microscopic granules cluster together, and form circles around the areolæ of the small mammillated eminences. The poriferous avenues are narrow, in which the holes are closely set in triple oblique pairs; in the three specimens before me the apical disc is either absent or concealed by the oolitic matrix. The mouth is small and decagonal. The margin is slightly notched, and divided into ten nearly equal-sized lobes; no reflection of the test is observed at the angles of the notches. The spines are unknown.

Affinities and differences.—This species is distinguished from *P. sublævis* by the rudimentary development of the secondary tubercles in the interambulacral areæ, which can only be said to exist at the internal side of the primaries, between the mouth and the equator; in the rest of the areæ they degenerate into granules. The other characters of the Urchin agree so well with Agassiz's very incomplete description, that we have not hesitated to identify it with the Swiss species. Our specimens are all much worn, and we know nothing of the apical disc.

Locality and stratigraphical range.—This Urchin was collected from the upper beds of the Inferior Oolite at Shurdington Hill, along with *Discoidea depressa* and *Clypeus sinuatus*.

History.—First described and figured by Agassiz in his 'Echi-

nodermes Fossiles.' Mr. M'Coy catalogues this species from the Great Oolite of Minchinhampton, but we know of no specimens from that locality; all the examples, five in number, examined by us, have been obtained from the upper beds of the Inferior Oolite.

Genus Echinus, Linnæus.

Test more or less globular. Ambulacra in general about half the width of the interambulacra; primary tubercles of nearly the same size in both areæ, and forming vertical ranges more or less numerous in the different species, but neither having perforated summits nor crenulations at their base; the poriferous avenues are well-developed; the pores are numerous, and disposed in transverse ranges in arched or triple oblique pairs; the mouth is large, of a circular or pentagonal form, and more or less divided at the margin by notches into ten lobes. The apical disc is composed of four nearly equal-sized ovarial plates, and a single larger madreporiform plate, and between the ovarial the five ocular plates are lodged. The masticatory organs or lantern are formed as in the genus *Cidaris*; but the pyramids are excavated in their superior part, and the two branches are united by an arch at the summit. The teeth are tricarinated.

Echinus perlatus, Desmarest. Pl. XIII. fig. 1 *a, b, c, d.*

Syn. *Echinus perlatus*, Desm. Dict. Sc. Nat. t. xxxvii. p. 100.
Echinus lineatus, Goldf. Petrefact. Germaniæ, t. 40. fig. 11.
Echinus germinans, Phillips, Geology of Yorkshire, pl. 3. fig. 15.
Echinus perlatus, Agassiz, Echin. Foss. de la Suisse, t. 22. fig. 13–15.
Echinus diademata, M'Coy, Ann. Nat. Hist. vol. ii. S. 2. p. 410.
Echinus multigranularis, Cotteau, Echinides Foss. de l'Yonne, p. 61. tab. 7. fig. 6–8.

Test hemispherico-conoidal with a pentagonal circumference; ambulacral areæ with two ranges of primary tubercles; interambulacral areæ furnished with two complete ranges of primary tubercles and six incomplete ranges of secondary tubercles, and a median depression in the centre of the areæ; apical disc small; anus eccentrical.

Height $1\frac{1}{2}$ inch, transverse diameter 2 inches.

Description.—The ambulacral are about one-half the breadth of the interambulacral areæ, and are very uniform in width throughout; they are prominent and convex, giving the circumference of the test of this beautiful Urchin a pentagonal form. The ambulacral columns have two rows of primary tubercles, about thirty in each row, placed on the poriferous borders of the plates, and from four to six tubercles between these rows at the base and angle of the test. The interambu-

lacral areæ are slightly convex, and taper very uniformly from the base to the summit. The lower half of the areæ is occupied by eight rows of primary tubercles, four in each column; at the base and for a short distance up the sides of the test, these tubercles are of a uniform size, but beyond this two rows only maintain their development, and numbering twenty-four pairs of primary tubercles in each area; the two external rows and the single internal row of tubercles are arrested in their development, and therefore become of a secondary size. The tubercles of both areæ are surrounded by a smooth areola encircled by a groove, on the external margin of which a wreath of small granules is disposed, reminding us of the granular zone surrounding the primary tubercles in the genus *Cidaris*. The intertubercular spaces of the areæ are filled up with small granules. The interambulacral areæ are separated along the median line by a somewhat depressed furrow, which is most conspicuous between the equator and the anal pole. This furrow arises from the convexity of the new-formed plates, and becomes less evident when the plates attain a greater width; this depression is likewise destitute of granulations, and affords a good specific character for this Urchin. The poriferous avenues are of uniform width on the sides of the test; they become slightly contracted at the basal angle, and expand from that point to the margin of the mouth-opening. The avenues have three pairs of holes disposed obliquely throughout, but increased to four or five pairs to fill up the increased spaces of the avenues in the vicinity of the mouth. The ovarial and ocular plates are in general preserved. The anal opening is always eccentrical, which gives the summit of the test an irregular form; the opening is placed forward, so that the madreporiform plate occupies nearly the centre of the anal polar axis. The pairs of ovarial and ocular plates are small and imperfectly developed.

The base is concave, and in this region all the primary tubercles of the interambulacral areæ attain their full development. The mouth-opening is large and decagonal, occupying nearly one-half the diameter of the base; the circumference is deeply notched with ten indentations which extend into the interambulacral areæ, and have their borders reflexed.

The spines are small, delicate, and subulate, but are very seldom found in connection with the test.

Affinities and differences.—We have, through the courtesy of Mr. S. P. Woodward, compared our Urchins with the typical specimens of *E. perlatus* in the Brit. Mus., and through the kindness of Professor Forbes with a specimen of *E. germinans*, sent by Mr. Phillips from Yorkshire; from this examination it is certain that the Gloucestershire and Yorkshire *Echini* are

the same species, and that the difference between them and the foreign *E. perlatus* from the evidence afforded by the test alone amounts at most to a more granular variety. We may consider therefore *E. perlatus,* var. *germinans,* as characteristic of the inferior stages, and *E. perlatus* of the upper stages of the Oolitic group. *E. diademata* of M'Coy agrees so nearly with our specimens of the young of this species that we think them the same.

Stratigraphical range and localities.—This Urchin is found in good preservation in the inferior ferruginous beds of the Pea-grit at Leckhampton, Cleeve, and Crickley Hills. Our best specimens were obtained from the latter locality; it is found in the shelly freestone of the above hills, and in the Inferior Oolite of Stroud, Nailsworth, Minchinhampton and Dundry; its convex prominent ambulacral columns, and the median furrow down the centre of the interambulacral areæ, serving to determine the species even when its other characters are effaced. On the continent *E. perlatus* is considered a characteristic Urchin of the "Terrain à chailles," and was long ago described by Desmarest. The specimens from the Inferior Oolite are more granular than those obtained from the upper stages of the Oolitic series, but in other respects the specific characters are identical.

History.—Echinus perlatus, figured and described by Desmarest and Goldfuss, has been long known to characterize the upper Oolitic beds of the continent. We have no doubt that Mr. Phillips's *E. germinans* is at most only a variety of this species found in the Inferior Oolites of England. Mr. M'Coy's description of *E. dimidiata* corresponds so closely with young specimens of this species, a series of which now lies before us, that we cannot doubt their identity.

Echinus serialis, Agass. Pl. XIII. fig. 2 *a, b, c, d.*

Syn. *Echinus serialis,* Agassiz, Echin. Foss. de la Suisse, t. 22. fig. 10–12.

Test hemispherical, depressed, circumference slightly pentagonal; ambulacral areæ with two rows of marginal tubercles; interambulacral areæ with two ranges of tubercles in the centre of the columns; base concave, mouth moderate-sized, decagonal, and slightly notched; apical disc small; anus slightly eccentrical.

Height 1 inch, transverse diameter 1 inch and $\frac{7}{10}$ths.

Description.—This Echinus resembles a *Diadema* in having two ranges of tubercles very nearly the same size on both areæ; the ambulacral are rather more than one-third the width of the interambulacral areæ, and are furnished with two rows of small tubercles, each alternate plate supporting a tubercle on its poriferous margin; the interambulacral areæ are wide, and have in

like manner two ranges of small tubercles, about twenty in each range, occupying the centre of the plates; the tubercles are raised on inconsiderable mammillary eminences surrounded by smooth areolæ, and encircled by a zone of small granules; the intertubercular spaces of both areæ are covered with similar small granulations; there are a few irregular secondary tubercles about the base, but none on the sides of the interambulacral or ambulacral areæ; the poriferous avenues are narrow, and occupied by numerous close-set pores arranged in triple oblique pairs; the basal angle is obtuse, and the base concave; in this region the tubercles are largest, and a few additional ones are introduced at each side of the central range; the mouth-opening is moderate, being $\frac{7}{10}$ths of an inch in diameter; it is nearly of a circular form, the marginal notches being of inconsiderable depth; the ovarial and ocular plates are small and preserved; in some of the smaller specimens the madreporiform plate is larger than the pairs of ovarials; the anus is situated before the single plate, and to the right side, and is therefore slightly eccentrical. The spines are unknown.

Affinities and differences.—The comparative smoothness of the test, and the absence of secondary tubercles, with the smallness of the marginal notches in the mouth-opening, form diagnostic characters by which we distinguish *E. serialis* from *E. perlatus*; the median depression between the two columns of interambulacra is likewise absent in this species.

Locality and stratigraphical range.—This species has been collected from the Inferior Oolite at Shurdington and Dundry Hills; the specimen from the latter locality is the one which has served for our description, the parts of the test which are broken being fortunately present in the smaller Urchin from the former locality; the Swiss specimens were found in the "Terrain à chailles" at Fringeli (Canton of Soleure), where it is very rare.

History.—First found by M. Gressly and figured and described by M. Agassiz in his 'Echin. Fossiles'; we are not aware of its having been noticed before as a British species.

Echinus granularis (Wright), n. s.

Test depressed, pentagonal; ambulacral areæ with two rows of tubercles; interambulacra with eight rows of tubercles, at the base and lower third of the areæ diminishing in size and number from six to four rows towards the apex; mouth large with marginal indentations; anus central; ovarial and ocular plates small.

Height $\frac{7}{10}$ths of an inch, transverse diameter $1\frac{1}{2}$ inch.

Description.—This Urchin is distinguished from the foregoing species by its depressed poles and pentagonal form, arising from

the prominence of the ambulacral areæ, which are not quite one-half the width of the interambulacral, and have two rows of tubercles throughout, and an additional row of from six to eight arranged between the marginal rows at the widest part of the areæ near the basal angle; the interambulacral areæ are wide and covered with tubercles; at the basal angle and lower third of the areæ we observe eight rows of tubercles, but at the upper part of the sides and near the apex there are only six rows: the specimen before us being much defaced about the apices of the areæ, this part of the test cannot be accurately described. The poriferous avenues are occupied with close-set pairs of pores arranged in triple oblique rows; the basal angle is obtuse, and the base is flat; the mouth is large and indented at the circumference; the ovarial and ocular plates are small, and the anus is central.

Affinities and differences.—The depressed test, pentagonal form, central anus and granular surface serve to distinguish this species from *E. perlatus*, which it much resembles. The same characters form a clear diagnosis between it and *E. serialis*, the number and smallness of the tubercles giving the upper surface of the test a rugous or granular appearance.

Locality and stratigraphical range.—This Urchin was obtained from the upper ragstone of Leckhampton Hill (Inferior Oolite), where it is rare; we have only seen three specimens of the species.

Genus Arbacia, Gray.

Small Urchins of a subspherical form, having the test covered with numerous small smooth-based imperforate tubercles, forming numerous rows on the ambulacral and interambulacral areæ; the pores arranged in rather deep avenues in single pairs; base concave; mouth large, margin with ten inconsiderable notches; apical disc narrow, prominent, and ring-shaped.

Arbacia Forbesii, Wright, n. s. Pl. XIII. fig. 4 *a*, *b*, *c*.

Test hemispherical; ambulacral areæ narrow, with four rows of small tubercles; interambulacral areæ wide, divided by deep median depressed lines, and covered with from twenty to thirty rows of small nearly equal-sized tubercles.

Height $\frac{9}{20}$ths of an inch, transverse diameter $\frac{1}{2}\frac{5}{0}$ths of an inch.

Description.—The test of this beautiful little Urchin is divided into fifteen unequal lobes; five of these are narrow and form the ambulacral, and ten are wider, forming the divided interambulacral areæ, which present an unusual appearance, having a median furrow descending down the centre of the areæ and dividing them into two equal convex conical lobes; the surface of the areæ is

thickly studded with small smooth tubercles; at the widest part there are from twenty-five to thirty rows; the number of these diminish at the apex and base, the basal tubercles are however larger than the others; the ambulacral areæ are narrow and of a nearly uniform width; they are furnished with four rows of small tubercles similar to those occupying the interambulacral areæ; they are in fact so closely set together that the plates are invisible, so that the test presents only a uniform granulated surface; the avenues are straight, narrow, but well defined; the pores are closely arranged in simple pairs; the base is concave and the tubercles in this region are larger; the mouth presents almost a pentagonal form in consequence of the wide straight arch made by the margin over the ambulacra and the small angles which the shallow notches make in the interambulacra; the apical disc is narrow and prominent; the madreporiform is larger than the pairs of ovarial plates, and the oculars are small, but apparently soldered into the angles formed by the ovarials.

Affinities and differences.—The greater number and the diminished size of the tubercles, with the deep median furrow down the centre of the interambulacral areæ, serve to distinguish *A. Forbesii* from *A. nodulosa*: as they are the only two forms of this genus hitherto found in our Oolites, these characters form a good diagnosis.

Locality and stratigraphical range.—This Arbacian was collected from the upper beds of the Inferior Oolite near Dundry, and we only know it from that locality. I have dedicated this species to Prof. Edward Forbes, to whose genius, talents, and learning natural history is so largely indebted.

Arbacia nodulosa, Wright. Pl. XIII. fig. 3 *a*, *b*.

Syn. *Echinus nodulosus*, Goldfuss, Petr. Germaniæ, t. 40. fig. 16. p. 125.

Test hemispherical, with a subpentagonal circumference; ambulacral areæ prominent and bounded by deep poriferous avenues; interambulacral areæ divided by a slight median depression; tubercles nearly equal-sized in both areæ, and arranged in longitudinal rows.

Height $\frac{7}{20}$ths of an inch, transverse diameter $\frac{11}{20}$ths of an inch.

Description.—This nodulated Urchin is hemispherical and has a subpentagonal form from the development of the ambulacral areæ, which are very prominent, especially at the basal angle; they are furnished with three rows of smooth prominent spherical tubercles set at short distances apart, the central row being absent at the base and apex of the areæ; the interambulacral areæ are twice the width of the ambulacral, and are occupied at their widest parts with about ten rows of tubercles, about the same size as those of

the ambulacral, and like them set distinct from each other, which gives the surface of the test a nodulated air; a slight furrow passes down the centre of the interambulacral areæ, dividing them into two parts; the rows of tubercles diminish in number at the apex and base of the areæ, they are larger and more fully developed, however, in the latter region; the apical disc is small, ring-formed, and prominent; the poriferous avenues are deep and strongly defined, the pores are arranged in simple pairs above, but they form double ranges which fill up the wide space at the basis of the areæ; the base is concave, the mouth is large and pentagonal like the former species, the notches are closely approximated at the bases of the interambulacra, and the marginal arch over the ambulacra is straight and wide; the tubercles disposed at the bases of both areæ are larger and more fully developed than those occupying the sides.

Affinities and differences.—The size of the tubercles and their diminished numbers when compared with *A. Forbesii* serve as a sufficient diagnosis whereby *A. nodulosa* may be distinguished from the former Urchin; the slight median furrow down the centre of the interambulacral areæ is very different from the deep line separating the areæ in *A. Forbesii* into two equal nearly conical lobes.

Locality and stratigraphical range.—This species was collected by my friend the Rev. P. B. Brodie from the bed of clay resting on the Stonesfield slate at Sevenhampton Common, along with *Acrosalenia spinosa* and *Pecten varians*; this bed occupies the same relative position in other parts of Gloucestershire, and is probably the basal clay band on which the shelly freestone beds of the Great Oolite rest. I only know the solitary specimen before me; in Germany, Count Münster found it in the Jurakalk of Baireuth.

History.—First figured and described as an *Echinus* by Goldfuss. I am not aware of its having been noticed before as a British fossil.

My thanks are especially due to Mr. W. H. Baily for the pains he has taken with the beautiful figures which accompany this paper, the original specimens of which are in my cabinet.

XXII.—*Observations on the Connexion between the* Crinoideæ *and the* Echinodermata *generally.* By Thomas Austin, F.G.S., Fort Major, &c.

In offering these observations and generalizations relative to the Crinoideæ, it is but an act of justice to acknowledge how deeply we are indebted to the laborious researches of those who have preceded us in this branch of inquiry. Among the writers on the Crinoideæ who have thrown considerable light on this im-